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GENETIC CHARACTERISTICS OF HONEY BEE BREEDING IN THE GANJA-GAZAKH REGION OF AZERBAIJAN

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ГЕНЕТИЧЕСКАЯ ХАРАКТЕРИСТИКА РАЗВЕДЕНИЯ МЕДОНОСНОЙ ПЧЕЛЫ В ГЯНДЖА-ГАЗАХСКОМ РАЙОНЕ АЗЕРБАЙДЖАНА

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Abstract. Beekeeping is one of the oldest and most profitable sectors of agriculture. Since ancient times, humans have bred, propagated, and maintained honey bees (*Apis mellifera* L.). The favorable soil and climatic conditions, along with the rich flora of Azerbaijan, create an ideal environment for the development of beekeeping. One of the challenges in bee breeding research is that honey bees mate in the air, often at considerable distances from their colonies. This complicates controlled breeding efforts. To address this issue, selection specialists are exploring artificial insemination techniques and the establishment of controlled mating zones. This article examines the development of beekeeping in Azerbaijan, with a particular focus on honey production in the Western region. Additionally, it explores the most effective modern approaches to bee breeding, especially in the context of increasing resistance to adverse environmental factors, which has become a critical priority in contemporary apiculture.

Abstract. Пчеловодство является одной из старейших и наиболее прибыльных отраслей сельского хозяйства. С древних времен люди разводили, размножали и содержали медоносных пчел (*Apis mellifera* L.). Благоприятные почвенно-климатические условия, а также богатая флора Азербайджана создают идеальную среду для развития пчеловодства. Одной из проблем в исследованиях по селекции пчел является то, что медоносные пчелы спариваются в воздухе, часто на значительном расстоянии от своих колоний. Это усложняет контролируемые усилия по разведению. Для решения этой проблемы специалисты по селекции изучают методы искусственного осеменения и создание контролируемых зон спаривания. Рассматривается развитие пчеловодства в Азербайджане с особым акцентом на производство меда в Западном регионе. Представлены наиболее эффективные современные подходы к селекции пчел, особенно в контексте повышения устойчивости к неблагоприятным факторам окружающей среды.

Keywords: honey bee, genetic characteristics, beekeeping, selection, breeding.

Ключевые слова: медоносная пчела, генетические особенности, пчеловодство, селекция, разведение.

A bee colony consists of a single queen bee, tens of thousands of worker bees, and thousands of drones. These colonies thrive in hives or nests, with beehives typically constructed as wooden boxes that can be relocated based on seasonal changes and environmental conditions. Beekeeping holds significant economic importance in Azerbaijan. Currently, the country is home to more than

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300.000 beekeeping families, and annual beekeeping fairs provide a platform for apiculturists to market and sell their natural bee products. The Beekeeping Center, operating under the Azerbaijan Scientific Research Institute of Animal Husbandry in the Ganja-Gazakh region, plays a crucial role in breeding and studying honey bees. The gene pool of Azerbaijan's bee populations consists of two primary breeds: the gray mountain Caucasian and the yellow Caucasian [13-15]. These two breeds encompass five distinct populations, contributing to the country's rich beekeeping heritage [4].

Honey bees mate in the air, often at a significant distance from their colonies, which presents a challenge for controlled bee breeding research. To address this issue, breeders are exploring artificial insemination techniques and the establishment of controlled mating zones. Initially, bee breeding research primarily focused on enhancing productivity. However, recent efforts have shifted toward developing genotypes with greater resistance to diseases and pests. In Azerbaijan, breeding research and development initiatives aim to preserve and enhance the genetic resources of honey bees, with a key focus on studying the effects of climate change and environmental factors on bee populations. Unfavorable environmental conditions, the spread of diseases and pests, improper beekeeping practices, and other negative influences contribute to the decline of bee colonies. Factors such as sudden climate fluctuations, depletion of floral resources, pesticide exposure, and increasing pest and disease threats adversely affect honey bee habitats. These challenges have led to a decline in the populations of this vital pollinator [1, 2, 12].

In Azerbaijan, honey bee populations primarily consist of local breeds, including the gray mountain Caucasian (*Apis mellifera caucasica* Worb) and the yellow Caucasian (*Apis mellifera caucasica flova*). Additionally, certain foreign breeds, imported from countries such as Turkey and Iran, are also present. The gray mountain Caucasian breed is predominantly cultivated in the Ganja-Gazakh region, where it has demonstrated strong adaptability to local climatic conditions. Azerbaijani breeders continue to protect and develop the genetic resources of native honey bee populations through ongoing genetic research. *Apis mellifera caucasica* Worb exhibits excellent winter hardiness, particularly in the western regions of the country, such as the Ganja-Gazakh zone. It also shows strong resistance to major bee diseases, including European and American foulbrood, nosematosis, and varroatosis. Moreover, this breed is distinguished by its high honey production capacity and a low tendency to swarming, making it highly valuable for apiculture. In Azerbaijan's beekeeping sector, effective colony management, queen rearing, and artificial insemination techniques are key strategies for achieving success in genetic improvement programs [5].

The queen bee serves as the genetic foundation of the colony. However, her natural mating process - occurring in flight and involving multiple drones - poses challenges for controlled genetic selection. To preserve and enhance the genetic resources of honey bees (*Apis mellifera L.*), the establishment of isolated and controlled mating zones, along with the implementation of artificial insemination, is essential. Controlled mating methods are particularly crucial for research focused on purebred and hybrid breeding, as they allow for precise selection and improvement of desirable genetic traits [3].

The primary objective of beekeeping is to enhance productivity. However, in recent years, the growing impact of diseases and pests has shifted the focus toward breeding honey bee populations with greater resistance [6].

Traditional chemical treatments used to control bee diseases and pests have proven insufficiently effective. Research indicates that these substances not only pose health risks to honey bees but also lead to residual contamination in hive-derived products, creating additional challenges [10].

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To ensure sustainable beekeeping, recent studies have increasingly emphasized genetic research and biotechnological advancements, aiming to develop more resilient honey bee populations while minimizing the reliance on chemical treatments [9].

Study on the breeding

The breeding technique for honey bees (*Apis mellifera caucasica Worb*) is a systematically planned and implemented approach aimed at the sustainable genetic improvement of the population [7].

Successful honey bee breeding requires meeting three essential conditions: 1) Clearly defining the selection goal - establishing the desired genetic traits and direction of improvement; 2) Reliable control of productivity - ensuring accurate assessment and monitoring of colony performance; 3) Selecting the most promising bees - carefully choosing superior queens and drones for mating to enhance desirable genetic traits. By adhering to these principles, breeders can accelerate the propagation of genetically superior colonies, ensuring stronger and more resilient bee populations.

In beekeeping, improving environmental conditions primarily refers to enhancing the internal hive environment, which serves as the colony's immediate surroundings. While optimizing hive conditions plays a crucial role in regulating the life of a bee colony, it alone is insufficient to maximize productivity. Sustainable and profitable beekeeping cannot be achieved solely through hive management practices; broader macroecological factors must also be considered. Key environmental factors influencing honey yield include climatic conditions, soil composition, altitude, and natural vegetation cover, as well as their seasonal variations and overall vegetation period. Understanding and adapting to these natural ecological conditions is essential for ensuring high productivity and long-term sustainability in apiculture.

Modifying or improving these environmental conditions is typically beyond the control of beekeepers and breeders. However, the Ganja-Gazakh zone offers optimal conditions for the development of beekeeping. The region's abundant and diverse natural vegetation provides a highly favorable environment for honey bee cultivation. Thus, achieving effective and profitable beekeeping requires maximizing the use of existing natural resources while simultaneously establishing productive bee colonies. Frühwirth emphasizes that while the availability of nectar in nature significantly influences honey yield, it is not the sole determining factor. Genetic traits also play a crucial role and cannot be overlooked in efforts to enhance productivity [6].

An improved methodology is essential for the genetic evaluation of honey bee populations. In addition to accounting for variations in heritability, it is important to consider the genetic correlation between the influences of the queen and worker bees when estimating breeding value [7]. Colonies with high breeding quality are those that exhibit superior heritable traits [8].

However, estimating the breeding value of honey bees is particularly challenging compared to other animal species due to the combined influence and interactions between the queen and worker bees within the colony.

Phenotype (P) is known to result from genetic (G) and environmental (E) influences, as well as their interaction. For diploid organisms, this relationship can be expressed as:

$$P = G + E + G \cdot E.$$

However, in honey bees, productivity is a colony-level phenotype, meaning that the formula must be adapted accordingly:

$$P_k = G_i + E_i + G_i \cdot E_i + G_a + E_a + G_a \cdot E_a + G_i \cdot G_a.$$

where, K – expresses the colony, a – expresses the queen bee, i – expresses the worker bee.

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It is important to note that when referring to the queen bee within a colony, we are speaking of a single individual, whereas the colony consists of numerous worker bees, each with a unique genetic makeup. Moreover, each worker bee experiences different environmental influences, further adding to the complexity of genetic evaluation.

However, given the current level of scientific knowledge and technological capabilities, it remains impossible to fully analyze and account for all these variables in such a complex system.

Thus, since the breeding value of a queen bee belongs to one individual, it can be calculated using the formula:

$$\text{Aa} = \frac{1}{2} A\text{a}_1 + \frac{1}{2} A\text{a}_2$$

where Aa – breeding value of queen bee, $A\text{a}_1$ – breeding value of mother of father of the queen bee, $A\text{a}_2$ – breeding value of mother of the queen bee.

For worker bees, only the average breeding value can be estimated, using the following formula:

$$\overline{\text{A}}_{\text{г}} = \frac{1}{2} A\text{a} + \frac{1}{2} \overline{\text{A}}\,\text{a}_3$$

where $\overline{\text{A}}_{\text{i}}$ – average breeding value of worker bees, $\overline{\text{A}}\text{a}_3$ – average breeding value of fathers and mothers of worker bees.

In this case, the average coefficient of relatedness among worker bees within a colony can be estimated using the following formula:

$$\overline{\text{R}}_{\text{ij}} = \frac{1}{2} + \acute{\phi})$$

Here, φ represents the probability that the allele inherited from the mother of a worker bee matches the corresponding allele in a related worker bee, while φ' denotes the probability that the allele inherited from the father of a worker bee matches the allele of her related worker bee.

These probabilities are essential for estimating the genetic relatedness among worker bees in a colony, which in turn influences colony dynamics, inheritance patterns, and selective breeding strategies. Improving colony quality often relies on comparative evaluations between different colonies. To ensure reliable and consistent results, experiments should be designed using standardized criteria for testing performance and assessing key selection traits. A variety of traits can be used to evaluate colony performance. While honey production is a directly measurable factor, other frequently assessed biological traits include: Population development, Swarming tendency, Dormancy, Overwintering ability, and Springing ability [8-11].

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